METALS AS FUEL.[1]

A CAREFUL metallurgist,[2] writing in the eighteenth century, claimed that "every matter which is combustible either wholly or in part, is called fuel, the pabulum of fire." The word is, however, usually restricted to substances which may be burnt by means of atmospheric air with sufficient rapidity to evolve heat capable of being applied to economic purposes. The latter definition covers certain metals, though it was doubtless framed to include only carbon and associations of carbon and hydrogen, such as coal. The omission from the definition of the reference to atmospheric air would enable the list of metals which might be used as fuel to be widely extended.

It has long been known that metals will burn, and it would be easy to show that the history of inorganic chemistry is epitomised and enshrined in a mass of litharge, which is simply burnt lead. Successive generations of chemists, from Geber in the eighth century to Lavoisier in the eighteenth, studied litharge carefully before the latter proved partly by its aid the identity of respiration, calcination and combustion. Into this history I need not enter, but it may be pointed out that Sir Isaac Newton[3] had a clear idea as to the possibility of burning metals. "Is not fire," he asks, "a body heated so hot as to emit light copiously?" . . . "for what else is red hot iron than fire?" and he significantly adds, "metals in fusion do not flame for want of copious fume." He was, moreover, aware that a mixture of lead and tin "suitably heated" does emit "fume and flame," and, in fact, a mass of 1 part tin and 4 parts lead, which looks metallic, will, if it is kindled, continue to burn like an inferior variety of peat, leaving an ash-like product which may be used as an enamel.

I propose to show that metals may be burnt for the sake of the heat and light they produce, just as ordinary fuels are burnt, except that in burning ordinary fuels combustion is often effected in two distinct steps or stages, in the first of which carbonic oxide is formed, and in the second carbonic acid, the products in both cases being gaseous. When metals are burnt, the products of combustion are solid, or condense to solids, and they therefore present a marked contrast to ordinary fuels which, as has just been stated, yield on combustion gaseous products. As I shall have but little to say about the light which attends the combustion of metals, I may as well dismiss the subject by reference to a familiar application of the burning of metals for the purpose of illumination. It is easy to fire electrically a portion of what is known as a "magnesium star," and a "fire-ball" of magnesium attached to a parachute is beautifully packed in this shell, for the loan of which I am indebted to the authorities of the Royal Arsenal, Woolwich, and when the shell explodes the stars burn and illuminate the enemy's position in the darkness of night, so that guns may be laid to place projectiles in the enemy's lines.

Before proceeding further, I want to use the electric furnace as affording a basis of comparison with the method of producing high temperatures by the combustion of metals, which I shall proceed to show subsequently. A current of 100 amperes at 200 volts is passed by carbon poles into the furnace in which pig iron is being melted; directly the last piece of iron has become fluid, the temperature of the fused pool must be about 1300° C. The fluid mass is reflected on the screen merely to give some indication as to the appearance of such a mass at 1300° C., and not to afford a test of the capabilities of the electric furnace. Later on I hope to show that a far higher temperature can be produced by very simple means in a receptacle of about the same capacity as the laboratory part of the furnace.

Henceforth in the course of this lecture metals will be burnt for the sake of the heat which is the result of their combustion. From this point of view metallurgists have long used metals as fuel, often without due recognition of the fact, but case after case could be cited in which conducting definite metallurgical operations is made possible by burning portions of the metal or metals under treatment. Time will perhaps be saved if I place in sharp contrast the use of ordinary fuel and metallic fuel, even though it takes us rather far back, for I do not want it to be thought

that the use of metals as fuel is new, although their adoption for this purpose has recently been greatly stimulated. Here is a mass of very ordinary iron ore picked up on a heath in Surrey, which skirts the site of what was once the ancient forest of Anderida. The pre-historic dweller on the heath who used the beautiful flint arrowheads, which are found near the iron ore, merely burnt the wood of the forest to warm himself or to cook his food. But the Britons whom Cæsar found in Andreaswold smelted iron with the wood of the forest trees, from which they prepared charcoal, and smelting iron was actively conducted in Queen Elizabeth's reign, and even survived into the last century in the district I am contemplating. But in smelting iron, carbon became associated with it and played a subtle part, rendering the iron precious for certain purposes and useless for others. Iron had therefore to be "decarburised" with a view to its conversion into steel, and in doing this metallurgists for centuries truly burnt some of the iron itself, using it actually as fuel. I will only add that the use of metals as fuel assumed magnificent proportions in the hands of Bessemer, as may be illustrated by an experiment. A few pounds of a compound of iron, carbon, silicon and manganese is melted in the wind furnace, simply used because it affords a convenient method of melting the mass, which is turned into a small Bessemer converter. A stream of oxygen is directed into the fluid mass. Air would do, but with so small a mass the free nitrogen would cool it too rapidly. In a few seconds the carbon in the fluid will be burnt away, nevertheless the mass gradually becomes hotter and hotter, notwithstanding the loss of carbon. A brilliant pyrotechnic display is the result. The metalloid silicon is now burning, and then brown fumes of iron and manganese pass freely off; these metals are truly burning and are maintaining the heat of the bath, and the presence of their fumes shows that it is time to stop the operation. The temperature is somewhere near 2000° C., but according to some recent investigations of Prof. Noel Hartley (*Phil. Trans.*, vol. cxcvi. series A, p. 479, 1901), a temperature of more than 2000° C. is attained in the converter. Bessemer gave the world in 1856 cheap steel; we therefore owe to him the inestimable benefits that are the results of that gift, and I ask you to bear in mind that his great service to the industry of which we as a nation are so justly proud rested on the possibility of using metalloids and metals as fuel. I have already promised that in the course of the lecture I will show some experiments in which the temperature will be a thousand degrees higher than in the one you have just seen. In the Bessemer process the products of combustion are both gaseous and solid, and in a very ordinary case the heat engendered by the carbon of the bath which evolves gases is only half that which results from the combustion of the silicon, iron and manganese which yield solid products. As regards the "open-hearth process," in the phase of it which is known as the "pig and ore" process, oxygen is presented and heat is produced under similar conditions to those we shall consider subsequently in the case of the action of aluminium on ferric oxide.

Heat Evolved by Burning One Gramme of the Following Elements.

Element.				Product of combustion.		Calories.
Aluminium ...	...	...	...	Al_2O_3	...	7250
Magnesium ...	...	...	...	MgO	...	6000
Nickel	...	...	...	NiO	...	2200
Manganese ...	...	...	...	MnO_2	...	2110
Iron ...	...	...	...	Fe_2O_3	...	1790
,, ...	...	...	...	Fe_3O_4	...	1580
,, ...	...	...	...	FeO	...	1190
Cobalt	...	...	...	CoO	...	1090
Copper	...	...	...	CuO	...	600
Lead ...	...	...	...	PbO	...	240
Barium	...	...	...	BaO	...	90
Chromium ...	...	...	...	Cr_2O_3	...	60
Silver	...	...	...	Ag_2O	...	30
Carbon	...	...	...	CO_2	...	8080
,,	...	...	...	CO	...	2417
Silicon	...	...	...	SiO_2	...	7830

This table, which contains the relative calorific powers of different metals and metalloids as compared with carbon, indicates the advantage which certain metals possess over carbon for use as fuel. The question at once presents itself, at what temperature will such metals as can be used for fuel begin to abstract oxygen from the air? The answer is, it depends on

the method by which the metals are prepared. If they are in a chemically active state, as lead is which has been prepared from tartrate of lead, they will, in many cases, take fire in air and burn at the ordinary temperature. This lead burns readily when shaken in air. If this mass of uranium, for which I am indebted to M. Moissan, is filed in air, the detached particles will ignite. Metallic iron which has been reduced by hydrogen from its oxide at a temperature below 700° C. will also take fire and burn in air at the ordinary temperature, a point of extraordinary interest in relation to the allotropy of iron (Osmond and Cartaud, *Ann. des Mines*, August 1900). Metals in this chemically active state are said to be "pyrophoric."

So far as I am aware, metals in this chemically active state have not been used as fuels. Neither am I aware that any use has been made of the allotropy of metals as enabling them to be used as fuel, but Prof. Graham once told me that pyrophoric iron had been suggested for warming ladies' muffs, the intention being to place the iron in a small receptacle and to admit air gradually as warmth was needed. Sir Henry Trueman Wood also remembers the suggestion, but tells me that he can find no record of it in the *Journals* of the Society of Arts. I may just mention that the burning of metallic antimony plays a very important part in roasting silver ores, and the behaviour of the metal is so peculiar while burning that I must pause to show it you. [A melted globule of antimony, if thrown on to a tray of paper, darts about and cannons from the sides, leaving a track of dark oxide on the paper.]

The metal I am going to employ as fuel is aluminium, the oxygen for its combustion being supplied by metallic oxides, which readily part with their ogxyen to aluminium if it be raised to certain definite temperatures. This question of the transference of oxygen from one metal to another, which results in the liberation of the metal attacked, is of special interest to us at the Royal Institution, for it undoubtedly originated within these walls and is due to Sir Humphry Davy. He discovered potassium in 1807, and in 1809 attempted to remove the oxygen from alumina by heating it with metallic potassium. He says (*Phil. Trans.*, part i. 1810, p. 60), "if I had succeeded in isolating the metal I should have called it *alumium*." His success was imperfect, but he certainly did obtain, by the intervention of metallic potassium, an alloy of aluminium and iron. It remained for Wöhler to prepare pure metallic aluminium from its chloride in 1827, and for Henri Saint Claire Deville, who began to work in 1854, to establish the metallurgy of aluminium on an industrial scale. As regards the reduction of metals from their chlorides, Wöhler (*Ann. der Chemie*, vol. cvi. p. 118) obtained crystalline compounds of chromium and aluminium and Michel (*ibid.*, vol. cxv. p. 102 ; *ibid.*, vol. cxiii. p. 248) compounds of aluminium with manganese, iron, nickel, tungsten, molybdenum and titanium. Levy (*Comptes rendus*, vol. cvi. p. 66) obtained an alloy of titanium and aluminium, Beketoff (*Ann. der Chemie*, vol. cx. p. 374) an alloy of barium with aluminium from the chloride of barium mixed with baryta. Dr. Goldschmidt (*ibid.*, May 1898) has given references to these authorities in a recent valuable paper. In 1856, Charles and Alexandre Tissier (*Comptes rendus*, vol. xliii. 1856, p. 1187) observed the fact which is the starting point of the experiments I have to show you. They found that aluminium decomposes the oxides of lead and of copper, much heat being evolved by the reaction.

They do not appear to have used aluminium in a finely divided state, and therefore failed to reduce certain metals from their oxides which are now known to be perfectly easy to reduce. It was not until comparatively recently that the use of aluminium for separating other metals from their oxides assumed serious proportions. Claude Vautin showed on June 13, 1894, at a soirée of the Royal Society, a few metals, and among them carbon-free chromium and manganese, which he had prepared, and as he undoubtedly gave the impulse that started much of the subsequent work in this direction, it may be well to give the description which was appended to the specimens he showed. It runs as follows :

Specimens of Metallic Chromium, Manganese, Tungsten Iron, &c., free from Carbon, also fused Alumina, obtained during reduction of the metallic samples.

The specimens of metallic chromium, manganese, &c., have been reduced from their oxides by means of metallic aluminium. The oxide of the metal to be reduced is intimately mixed with finely divided aluminium, and heated in magnesia-lined crucibles. The heat produced by the oxidation of aluminium during the operation is sufficient to fuse alumina, a specimen of which is exhibited.

The subject is, however, in a sense your own, for, so far as I know, the lecture on "The Rarer Metals and their Alloys" (NATURE, May 2 and 9, 1895), which I delivered here in 1895, was the first occasion on which the reducing action of aluminium was demonstrated on a comparatively large scale, and covered an extended series of metallic oxides. Since that time great progress has been made, the most noteworthy advance being in the direction of the use of aluminium for the sake of the heat afforded by its combustion as a true fuel, the oxygen being derived, not from the air, but from a metallic oxide. In order that I may be clear, let me repeat that when coal is burnt the oxygen is derived from the air. When aluminium is used as a fuel the oxygen is derived from a metallic oxide, the metals change places, the aluminium is oxidised,
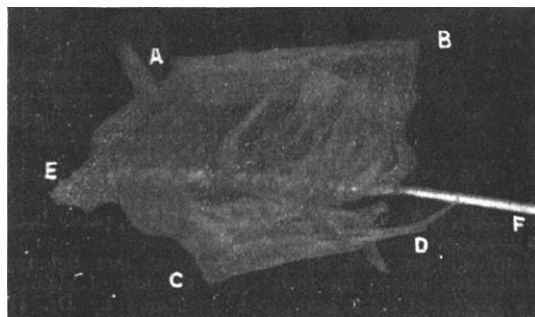

FIG. 1.—The oxidation in air of an amalgamated wire of aluminium, E F. The films of alumina, A B and C D, are those which first formed on the wire.

and the other metal set free from its oxide. This part of the subject must be carefully approached, and the question at once arises as to what extent the aluminium must be heated before it will begin to abstract oxygen from air or from an oxide. It is well known that the metal aluminium will not oxidise sensibly in the air at the ordinary temperature, but the presence of a little mercury enables it to oxidise readily. Le Bon (*Comptes rendus*, October 29, 1900, p. 707) has shown how minute the quantity of mercury may be. This wire of aluminium to which a thermo-couple is attached will, if a mere trace of mercury be rubbed on its surface, become rapidly heated by oxidation, the temperature rising to 102° C., while at the same time a fungoid-like growth of alumina forms on its surface (see Fig. 1). Aluminium foil will burn readily in oxygen if its combustion
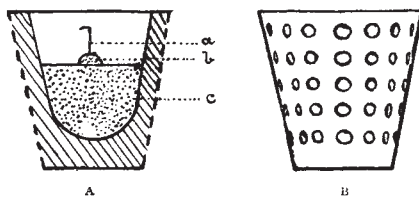

FIG. 2.—Crucible in which the reduction of metallic oxides is effected. A, diagrammatic section of the perforated sheet-iron crucible, B, lined with magnesia ; *c* is the mixture of aluminium and the metallic oxide to be reduced to metal ; *a* is a piece of magnesium ribbon placed in a mixture, *b*, of aluminium and some readily reducible oxide.

be started by a glowing fragment of charcoal. The temperature at which aluminium will abstract oxygen from a metallic oxide will depend on the oxide submitted to its action. Three cases may be taken : (1) Lead oxide and granulated aluminium may be ignited by a match, as may also silver oxide (Ag_2O), for it parts with its oxygen very readily. (2) Chromium oxide (Cr_2O_3) and granulated aluminium burns slowly and requires rather a high temperature to start the reaction. Oxide of iron (Fe_2O_3) and granulated aluminium also requires the presence of a readily reducible oxide to start the reaction. On the other hand, (3) a mixture of sodium peroxide, carbide of calcium and granulated aluminium may be started by a drop of water by the mere inflammation of the acetylene. In all these cases, or in any other case, the products are solid, for if any of the

reduced metal is volatilised it soon condenses, and may be collected, usually in an oxidised form.

In using aluminium as fuel the object, of course, is to produce intense heat, and returning to this mass of iron ore from the Surrey heath it may at once be stated that an oxide of iron,
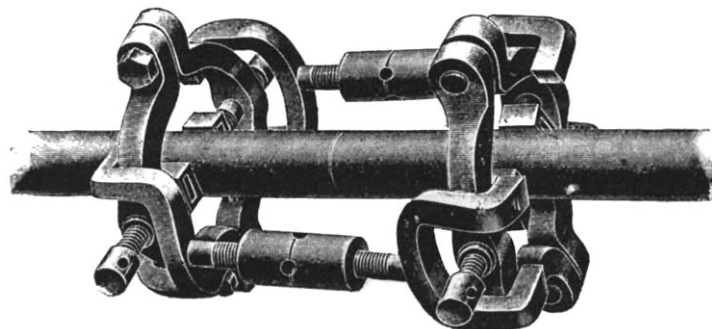

FIG. 3.—The clamps used or welding tubes up to four inches in diameter.

ferric oxide, is the most convenient oxide to use, partly because it is inexpensive.

Many of my audience already know that the recent investigations having for their object the use of aluminium as a source of heat have been conducted by Dr. Hans Goldschmidt, of Essen, and it is through his labours that metallurgy enters upon an entirely new phase. It would be difficult to offer him fuller or more unstinted praise than that. You will, I trust, soon realise how much industry is indebted to him. In its simplest form his process consists in igniting a mixture of oxide of iron, ferric oxide and finely divided aluminium. To this mixture the name of "thermit" has been given, and several varieties of it, adapted to various kinds of work, are used by Dr. Gold-schmidt at the works of the Allgemeine Thermit-Gesellschaft at Essen-Ruhr.

The mixture is placed inside a crucible (Fig. 2) and is ignited by a small piece of magnesium wire, which serves as a kind of wick if it is placed in a little heap of calcium sulphate and aluminium. Such a mass will now be lighted, and you see intense heat is produced. [When the operation was conducted in accordance with the above in-dications, the theatre was brilliantly illuminated by the intense light produced. A mass of metallic chromium weighing about 100 lbs., reduced to the metallic state as above described, was exhibited.] The aluminium abstracts oxygen from the oxide of iron, and a sufficiently intense heat is produced, not only to melt

FIG. 5.—Casing packed round with moulding sand in readiness for the welding operation.

the iron which is liberated from its oxygen, but to melt up the slag and, further, to leave a considerable surplus of heat, which is available for doing other work. No known pyrometer will enable the heat to be measured. I believe it to be about

3000° C. The aluminium plays the part of a fuel, and this table shows the advantage aluminium possesses as compared with carbon for the particular work required of it.[1]

The Reduction of Fe_2O_3 *to Iron by Aluminium and by Carbon.*

	Aluminium.	Carbon.
Compound produced ...	Al_2O_3	CO
Amount of reducing agent required to produce 1 kilo. of iron ...	0·484 kilo.	0·321 kilo.
Amount of heat produced by oxidation of the reducing agent ...	3456 calories	770 calories
Heat required to reduce the Fe_2O_3	1796 ,,	1796 ,,
Heat required for fusion of the slag	548 ,,	
Heat required for fusion of iron	362 ,,	
Total heat required ...	2706 ,,	1796 ,,
Residual heat available	750 ,,	− 1026 ,,

On the aluminium side some 750 calories (units of heat) are available to do work (3456 − 2706 = 750 calories). On the carbon side there is a de-ficiency of no less than − 1026 calories. As regards the crucibles, they may be made of alumina, the solid product which is the result of the combustion of aluminium. They may also be made of mag-nesia or mended with magnesia. I shall have more to say about the solid product of the combustion subsequently. The practical
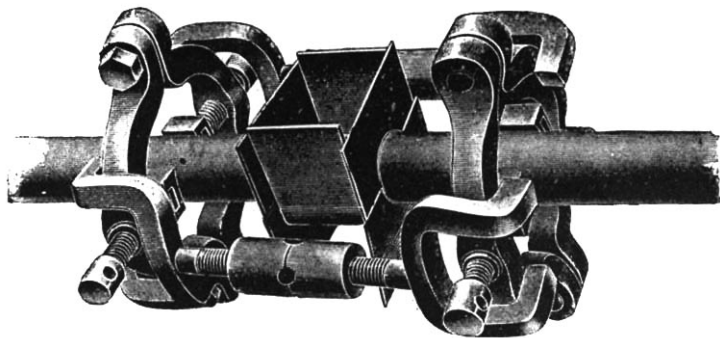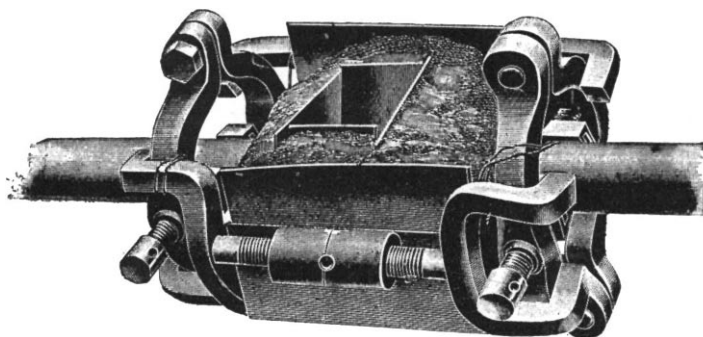

FIG. 4.—Tubes clamped together with a casing of thin iron round the junction to be welded.

application of the process is as follows. The ignited and molten mass in the crucible is so intensely hot that it may be made to unite surfaces of steel that require to be joined, such as the ends of lengths of rails. If I may use a simile which enables me to describe the method rapidly, the fluid contents of the crucible are applied as a hot bandage might be applied to wounded or severed surfaces in the human body which require medical treatment to facilitate healing or to cause them to unite. It may be objected that the fluid contents of the crucible would set as a whole round the metallic junction and give trouble, but this is not the case, for a layer of fluid alumina appears both to coat the rod, tube or rail which has to be welded, and to set in a mass which can be readily detached after the work is done. The casings (Figs. 4 and 5) are protected in the same way. The diagrams (Figs. 3, 4, 5) need but little comment, as they sufficiently indicate the method adopted in the case they represent. These figures were used to illustrate a paper by Mr. E. F. Lange (*Journal* of the Iron and Steel Institute, 1900, No. ii. p. 191). [I was indebted to him for the loan of small appliances of a similar kind to enable me to demonstrate to the audience the welding of steel tubes, and the operation was shown on as large a scale as safety would

permit.] The welding of three miles of electrical tramway rails was successfully effected in Brunswick in May 1900.

As regards the comparison of the use of aluminium as fuel with the electric arc, M. Camille Matignon (*Moniteur Scientifique Quesneville*, No. 702, Juin 1900, p. 357 *et seq.*), in a very interesting discourse recently delivered in Paris, has instituted a comparison between the Goldschmidt process and the electric furnace. Quoting Moissan ("Le Four électrique," p. 19), he shows that in reducing titanic acid by carbon in the electric furnace having a "laboratory space" of 800 cubic centimetres, 300 horse-power absolute were employed, producing per second 190,500 calories by burning 1'08 kilograms of aluminium. On the other hand, by burning 3'2 kilograms of ferric oxide during one minute in a crucible of about the same
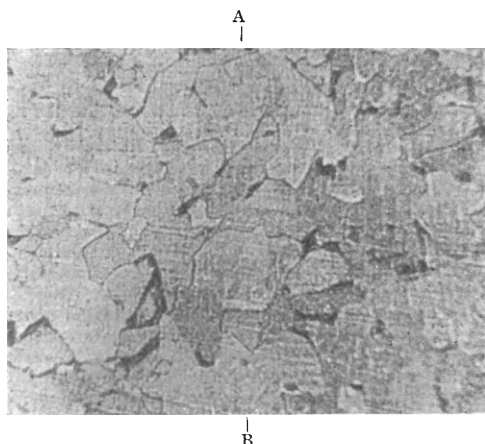
A
|

|
B

Fɪɢ 6.—Section of the welded test piece (Fig. 7), showing crystals passing across the line of weld, A B. Magnification, 140 diameters.

capacity as the laboratory of the electric furnace, the rate of evolution of heat is equivalent to 375 horse-power absolute ; the latter process does not, however, work continuously, but could readily be made to do so. It should be pointed out that an impure variety of aluminium can be used, and that if the heat needed to effect a given operation is but moderate, the aluminium may be diluted by the presence of an inert substance.

The photomicrograph (Fig. 6) is from a little test piece of wrought iron (Fig. 7) which was cut in two. The carefully faced surfaces were then clamped together, and I united them into an excellent weld, without any previous experience in conducting such an operation. No line of demarcation can be seen, and the crystals pass over the line A B, which I know by measurement to be that of the actual weld.
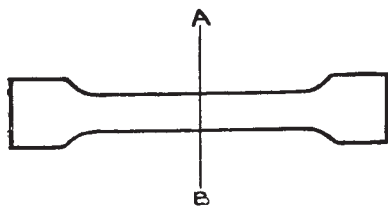
A

B

Fɪɢ. 7.—Test piece of wrought iron welded at A B. See Fig. 6 for micro-section.

The very hot molten iron may be used in a somewhat different way for repairing defective castings. In this case the slag is carefully poured off the fluid iron in the crucible and the iron is then poured into the defective part in the casting which it is required to mend, a guiding rim of some refractory material being provided. By mixing other metallic oxides with the iron oxide, the metals they contain are reduced and alloy themselves with the iron, and the composition of the defective casting can thus be matched. In connection with the repairs of fractured or defective steel castings, the possibility of producing directly steel of a suitable degree of carburisation is important. This may readily be effected by mixing fragments of cast iron with the "thermit," thus 70 to 90 grammes of cast iron mixed with 1000 grammes of

thermit gives a very fine-grained and workable steel. One useful application of the process is for locally softening hardened armour plates in the positions where the bolts and screws have to be inserted through the holes drilled to admit them. This is effected by placing a little fluid "thermit" on the spot where the plate has to be drilled and the heat softens the hardened surface. It should also be remembered that, with reference to the repairs of defective parts of machinery, a suitable admixture of metallic oxides with the ferric oxide, such as those of chromium, nickel or manganese, may be reduced together with the iron derived from the ferric oxide. Richly carburised iron may be added to the molten mass, and in this way any quality of steel may be produced.

This latter reference to metallic oxides reminds us of the original use for which the finely divided aluminium was employed, namely, as a reducing agent for the rarer metals and not for the sake of the heat evolved by the reaction. This portion of the subject I dealt with at the Royal Institution six years ago, but there have been great advances since. It would have been tedious to have conducted the experiments before you, as the crucibles would have taken so long to cool; but in each of these crucibles, which will now be broken open, I hope to find a small mass of metal, which, until now, has not left the spot in which it was reduced. [About a pound of nickel and a pound of cobalt were then produced from the respective crucibles in which they had been reduced].

Manganese and chromium containing only small quantities of carbon are now produced on a large scale for industrial use. As regards the reduction of metals and alloys from their oxides by burning aluminium, the following are the most recent results that have been obtained (*Stahl und Eisen*, March 24, 1901). The use of carbon-free chromium in connection with the metallurgy of steel is an exceedingly useful development of the methods we have considered. Hitherto, the addition or ferro-chrome to steel has involved a loss of from 20 to 25 per cent. of the chromium, while with pure chromium the loss is slight. Moreover, the addition of ferro-chrome incidentally raises the percentage of carbon, and steel containing, for instance, 2'5 per cent. of chromium should not have more than from 0'15 to 0'20 per cent. of carbon, and this can only be attained by the use of pure chromium. In the manufacture, also, of tool steel, the percentage of chromium may reach from 6 to 10 per cent. and even higher, a result which is only rendered possible by the use of pure chromium. In the same way, in connection with the metallurgy of copper, the possibility of providing carbon-free manganese is important, as is also the preparation of cupro-manganese free from iron. Alloys of manganese with zinc and with tin are likely to prove of value. Many uses have been found for the alloy containing 80 per cent. of zinc and 20 per cent. of manganese, while it is anticipated that the alloy containing 50 per cent. of tin and 50 per cent. of manganese will also prove to be important. Use has also been found for an alloy of 70 per cent. manganese and 30 per cent. chromium. Ferro-titanium, with 20 to 25 per cent. of titanium, and alloys of titanium and manganese containing from 30 to 35 per cent. of titanium, have also been produced. Titanium, moreover, absorbs nitrogen, and ferro-titanium is found to be very useful in producing sound steel castings. I, quite independently o. Dr. Goldschmidt, succeeded in the preparation of alloys of iron with from 3 to 25 per cent. of boron, the alloy containing 3 per cent. of boron proving to be beautifully crystallised. Dr. Goldschmidt states that definite results have not been obtained in attempts to utilise it. I am still investigating this most interesting subject. Dr. Goldschmidt has obtained ferro-vanadium, the best results being given with steel containing 0'5 per cent. of vanadium. He has also prepared an alloy of lead and barium containing 30 per cent. of barium, which affords an example of the possibility of forming alloys of metals with those of the alkaline earths by this process.

It only remains for me to direct your attention to the nature of the solid product of the combustion of aluminium, which is alumina often of a high degree of purity, and in a specially interesting form. The alumina from the reduction of oxide of chromium, when it is allowed to cool, forms large ruby-tinted crystalline masses, closely resembling the natural ruby. I have now to show you on the screen some rubies and sapphires produced as an incident of this beautiful process. The blue sapphire mass is, however, only translucent, not transparent. The ruby crystals are often very beautiful, as these slides show. Rubies placed in a vacuum tube and subiected

to the bombardment of an electric discharge are, as Sir William Crookes has taught us, beautifully phosphorescent. I have here in this tube some thin crystalline plates of artificial ruby ; they become beautifully phosphorescent when the current from the induction coil is passed through the tube, and by the kindness of Sir William Crookes I can show you some true rubies treated in a similar way. The behaviour of the artificial rubies in the vacuum tube is not quite as brilliant as that of the natural ones, but hitherto no special attention has been devoted to their preparation ; they are simply thin plates broken from a large crystalline mass of slag such as that on the table. I may add that this variety of corundum produced by the burning of aluminium is very hard, and may be used, not only for the same purposes as ordinary corundum, but for lining the crucible in which the operations are conducted, so that the product of combustion takes its place in conducting the process. My warmest thanks are due to Dr. Goldschmidt for lending me the beautiful specimens on the table, and to Mr. W. H. Merrett for his aid in conducting the experiments.

I have set before you the considerations respecting the use of metals as fuel simply as they appear to flow. I trust that the adoption of the title of this lecture has been justified by the evidence given as to the possibility of using metals as fuel in the strictest sense of the word. It is well to be accurate on this point because we are told that the first known appearance of the word " fuel " in the English language occurs in a poem (*Coeur de Lion*, 15th century), and seems to have been a misinterpretation of the old French word *fouaille*, and was adopted in the belief that sustenance for the body and food for the flames are synonymous. Widening our view of metals by grouping them with fuels will be acceptable because fire and flame powerfully appeal to our thoughts. We " kindle " enthusiasm, and add " fuel " to the fire of ambition, in fact we constantly use fire, flame and fuel as similes, and any prospect of extending their use to us as such by enlisting metals in the service will be welcome. An early Italian metallurgist, Vanoccio Biringuccio, might not have thought so, for I find that, writing in the sixteenth century, he quaintly devotes the last chapter of a work on metallurgy to " Fires which burn and leave no ashes."[1] In this chapter he appeals to envy, hatred, malice and other products of a kindled imagination, and traces their analogies to fuel and flame, but he speedily takes leave of his readers in alarm at the prospect such a treatment of the subject presents.

The burning of aluminium as fuel gives us sapphires and rubies in the place of ashes, and metallic fuel is burnt, not by the air above, but by the oxygen derived from the earth beneath, as it occurs in the red and yellow oxides to which our rocks and cliffs owe their colour and their beauty.

AGRICULTURAL EXPERIMENTS.

A NUMBER of reports on agricultural experiments conducted by provincial colleges have reached us, of which the most comprehensive is that issued by the Agricultural Department of the Durham College of Science. Most of the field-work that this report deals with was planned and started by Prof. Middleton's predecessor, and the results are becoming more valuable each year. It is a report that should be in the hands of every one that is interested in agricultural progress, though no one need expect to find it light reading.

In the north of England, as in many other parts of the country, the turnip crop suffers severely from finger and toe, and the work of the Durham College of Science is throwing much fresh light on this subject. Hitherto the disease has chiefly been combated by the application of large dressings of slaked lime applied a year or less before it was intended to grow a cruciferous crop. In this way the fungus and its spores are destroyed more or less effectively, but at a larger cost than agriculture can now well bear. It appeared, however, that if lime can get rid of the disease when the substance is applied only a short time before the crop that the fungus affects is to be grown, the clearance of the soil will be much more effectual—or will be accomplished at less outlay—if the trouble is attacked at its fountainhead, namely, directly after an infected crop has been grown. With this object in view, a field that had grown a much-diseased crop

[1] " De la Pirotechnia," 1540, p. 167. (Venice). "*Del fuocho che consuma et non facenere.*"

in 1896 was divided into five plots in the autumn of that year, one of the plots being soon afterwards treated with 2½ tons per acre of ordinary burned lime, while another plot did not receive its dressing till the autumn of 1899. Following the four-course shift the field was again under turnips in 1900, with the following result per acre :—

	Weight of roots		Percentage	
	Sound	Diseased	Diseased and destroyed	Sound
	Tons cwt.	Tons cwt.		
No lime	13 18	2 17	41·6	58·4
Lime applied, Feb. 1897...	20 11	0 13	10·1	89·9
,, ,, Nov. 1899...	15 12	1 13	29·2	70·8

The above figures hardly put the case so strongly as they might, for whereas when the roots were diseased to the extent of 41·6 per cent. and 29·2 per cent., such roots were practically valueless, the infected roots were far from the putrescent stage when the percentage of disease was 10·1.

The now well-known Cockle Park experiments on " manuring for mutton " are described at length in the above report, and are popularly presented in a circular issued by the Northumberland County Council. In this circular the results for each plot are shown by a diagrammatic sheep, the sections of whose body represent (*a*) the growth due to the soil in its unimproved condition ; (*b*) the growth induced by manurial treatment ; and (*c*) the portion of such growth as is needed to cover the manurial outlay. So far a large dressing of basic slag applied four years ago, and not repeated, has proved most effective ; whereas the lowest place is taken by a moderate dressing of lime. A corresponding circular deals with the experiments on turnip manuring.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

A WELL-ARRANGED calendar of the Merchant Venturers' Technical College, Bristol, showing the courses of work to be taken in the forthcoming session and the facilities for study, has been received. At the end of each syllabus a useful list of books of reference is given, in addition to the usual list of text-books. We assume that the reference books recommended are to be found in the school library, or on the laboratory bookshelf.

A VACATION course of lectures and observations connected with nature study, for teachers in rural schools, was opened at the Harper-Adams Agricultural College, Newport, Salop, on August 1 with an address by the principal, Mr. P. Hedworth Foulkes. The primary object of nature teaching is, he pointed out, to encourage and promote in children the power of observation, so that when the school days are over the pupil is in full and complete sympathy with natural knowledge, and takes an intelligent interest in it. The course has been arranged to help teachers who are desirous of cultivating this spirit of observation and inquiry in their pupils.

PROF. W. J. ASHLEY, now one of the professors of economics in the Harvard University, Cambridge, Massachusetts, has been appointed to the first or organising chair of the future faculty of commerce in the University of Birmingham. Prof. Ashley was a Brackenbury scholar at Balliol College, Oxford, and obtained a first in history in 1881, followed by a fellowship of Lincoln College. For three years he was college tutor in Oxford, lecturing in large classes in economics and history. Towards the end of the eighties he was called to a chair of economics at Toronto, and after a short time the staff of Harvard University went out of the ordinary course to enable provision to be made among them for him, and there he has occupied the chair of economic history since 1892, the chair of economics itself being held by Prof. Taussig. It is understood to be the wish of the council and senate of the University of Birmingham that the professor should devote his first year to investigation and consolidation of ideas, in consultation with men of business in this and other countries,